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A STUDY OF THE SPACE AND TIME STABILITY OF A NARROWBAND LONG-RA--ETC(U)
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A Study of the Space and Time Stability of a Narrowband Long-Range Acoustic Signal in the Ocean.

A Paper Presented at the ~~100th~~ Meeting of the Acoustical Society of America, Los Angeles, California, 20 November 1980.

(100.1)

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Preface

This document was prepared under the Ocean Measurements and Array Technology (OMAT) Program portion of the SEAGUARD Program sponsored by the Defense Advanced Research Projects Agency (ARPA Order No. 2976), Program Manager, V. Simmons, Tactical Technology Office and Naval Electronic Systems Command, Program Manager, CAPT H. Cox, PME-124; NUSC Project No. B69600 and B69605, Program Manager, R. F. LaPlante.

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REPORT DOCUMENTATION PAGE

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Bandwidth Stability
Doppler Shift
Multipath Phenomena
Narrowband Processes
Signal Stability
Transmission Phenomena

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document presents the oral and visual presentation, entitled "A Study of the Space and Time Stability of a Narrowband Long-Range Acoustic Signal in the Ocean," presented at the 100th Meeting of the Acoustical Society of America, 20 November 1980, in Los Angeles, California.

A study is made of the stability of the principal parameters of a narrowband acoustic signal transmitted over a long range to a field of

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20. Continued:

receivers. Measurement is made of the center frequency, bandwidth, and peak intensity as a function of both space and time. The relative stability of each parameter is determined and the possibility of identifying a single distrubance event is discussed.

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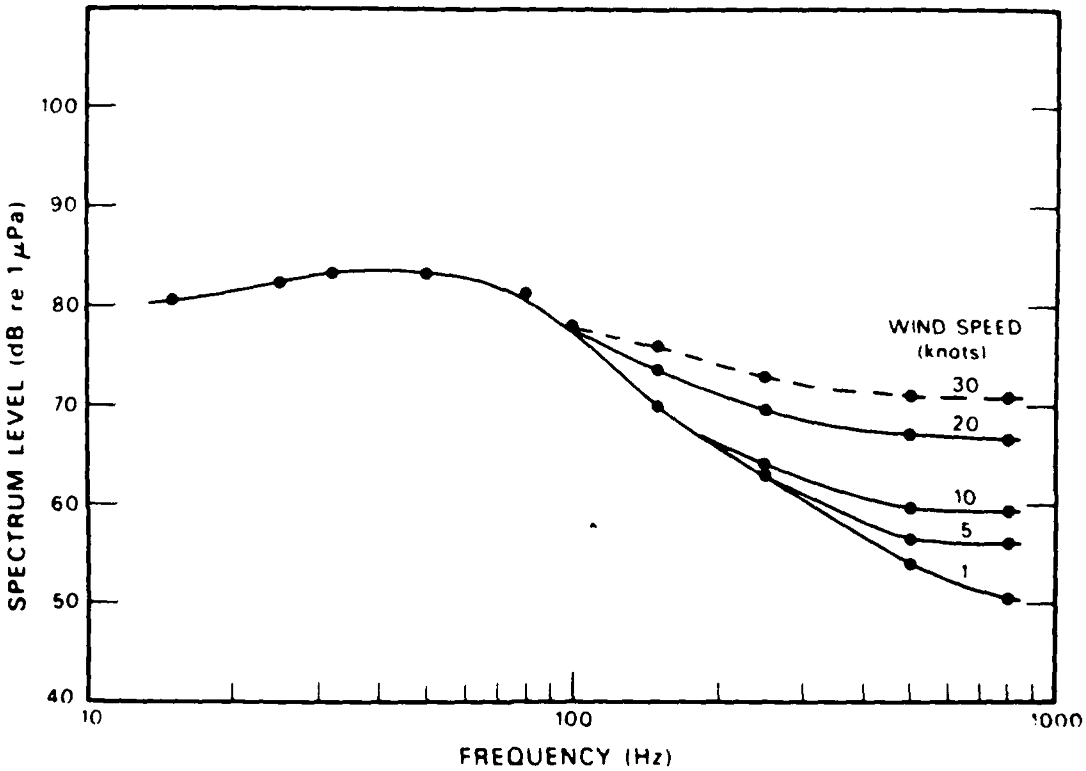
A Study of the Space and Time Stability of a Narrowband Long-Range Acoustic Signal in the Ocean

— Slide 1, please. —



(From G. B. Morris, "Depth Dependence of Ambient Noise in the Northeastern Pacific Ocean, J. Acoust. Soc. Am., vol. 64, 1978, pp. 581-190.)

Slide 1

The dominant factors in deep water ambient noise are now well known. For example, in heavily trafficked ocean areas, a relatively constant shipping noise dominates below 100 Hz; wind dependent noise dominates above 100 Hz.

However, although a particular mechanism dominates, other mechanisms can also make a significant contribution, especially if we can differentiate between them. Hence, there is much present interest in determining the characteristics of all components at low frequencies.

— Slide 2, please. —

LOW FREQUENCY AMBIENT NOISE

1. WIND GENERATED NOISE

2. BROADBAND SHIPPING NOISE

3. NARROWBAND SHIPPING NOISE

Slide 2

Low frequency ambient noise has three major components. Recent experimental measurements in the Southern Hemisphere, and supporting theory by Kuryanov and others, now gives us a reasonable understanding of wind generated noise down to at least 10 Hz.

Broadband noise has been historically well studied by octave band analysis.

It is narrowband noise that is presently the least known.

— Slide 3, please. —

NARROW BAND | **OCEAN INTERACTION** → | **BROAD BAND**

1. SCATTERING

2. MULTI-PATH

3. DYNAMIC EVENTS

Slide 3

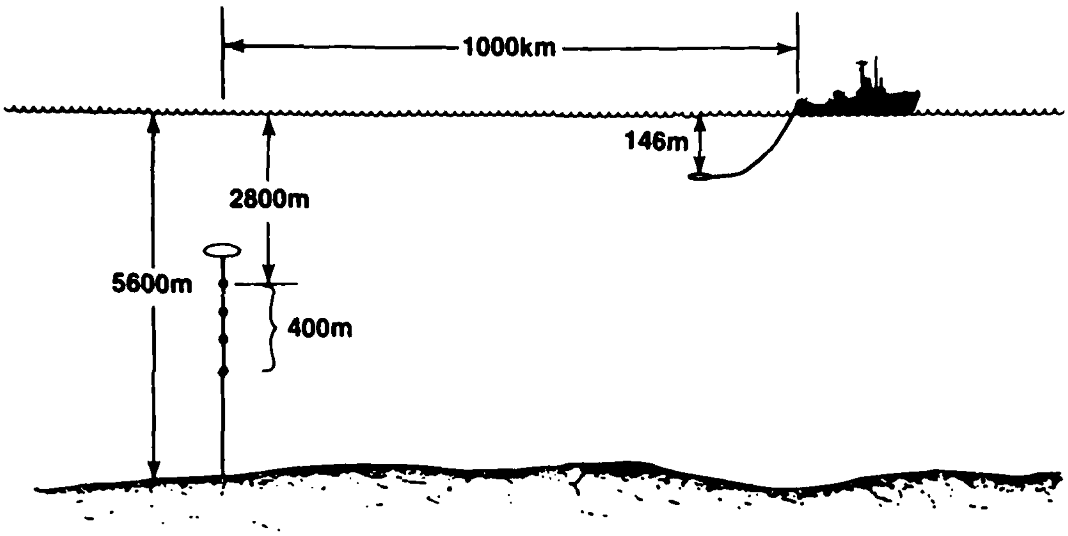
Concerning narrowband noise, there is one key question

> Does the spatial inhomogeneity and temporal instability of the ocean cause narrowband noise to be transformed into broadband noise?

There is evidence from propagation experiments that ocean inhomogeneities can affect sound. This has resulted in various theories — simple scattering such as developed by Mellen, more sophisticated multi-path theories to predict fluctuations, and finally the linking to dynamic ocean events such as internal waves.

Although some of these theories, as well as the reports of the Jason Committee, apparently provide the theoretical basis to calculate such an effect, frankly it was just easier to make the measurements.

— Slide 4, please. —



Slide 4

What we did was simply tow a narrowband low-frequency source at long range (1000 kilometers), receive on four hydrophones, and see what happened. The source depth was 146 meters; the total aperture of the hydrophones was 400 meters, located near the middle of the water column at a depth of approximately 2800 meters.

— Slide 5, please. —

DATA MATRIX

	T_1	T_2	■	■	■	T_{10}	TIME
H_1	●	●	●	●	●	●	$\bar{T}_{H1}$
H_2	●	●	●	●	●	●	$\bar{T}_{H2}$
H_3	●	●	●	●	●	●	$\bar{T}_{H3}$
H_4	●	●	●	●	●	●	$\bar{T}_{H4}$
SPACE AVERAGES	$\bar{S}_{T1}$	$\bar{S}_{T2}$	▲	▲	▲	$\bar{S}_{10}$	

Slide 5

The data are presented in this way. The four hydrophones are designated H_1 through H_4. Data were collected simultaneously on each hydrophone for an 18-minute period. This was done ten times at 9-minute intervals that resulted in a 50% time overlap.

We therefore can obtain ten space averages by combining the data from each hydrophone at a given time; and four time averages by averaging the data from a single hydrophone over the ten time intervals.

This makes it possible to compare relative changes in time and space albeit for the arbitrary time intervals and hydrophone spacing that we have.

— Slide 6, please. —

BANDWIDTH STATISTICS

SPACE AVERAGE		
TIME (min)	$\overline{S}$ (mHz)	σ (mHz)
0	4.0	.5
9	3.4	.5
18	3.0	.3
27	3.4	.4
36	3.5	.9
45	3.9	.9
63	4.1	1.0
72	4.1	1.2
81	4.6	1.0
90	4.3	0.9

TIME AVERAGE		
HYDRO-PHONE	$\overline{T}$ (mHz)	σ (mHz)
H_1	3.8	.7
H_2	4.4	.9
H_3	3.8	.8
H_4	3.6	.4

Slide 6

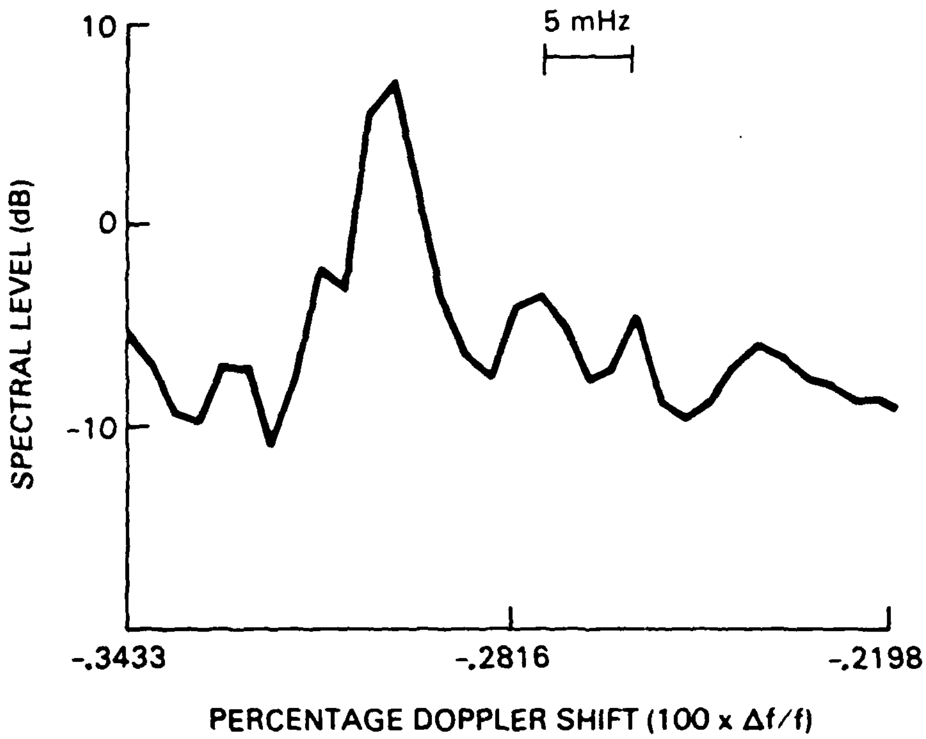
Logically the first parameter to look at is bandwidth. Our results showed that in both space and time, the average bandwidth of our signals received at 1000 kilometers is still very narrow — about 4 millihertz. You can see that both the average bandwidth and standard deviation are very similar in both space and time.

It appears that narrowband signals have not become broadband signals at this range, hence, simple scattering is not a significant factor.

According to the work of Flatte, we are near the boundary between strong and weak scattering; however, our data indicates weak scattering is still dominant.

— Slide 7, please. —

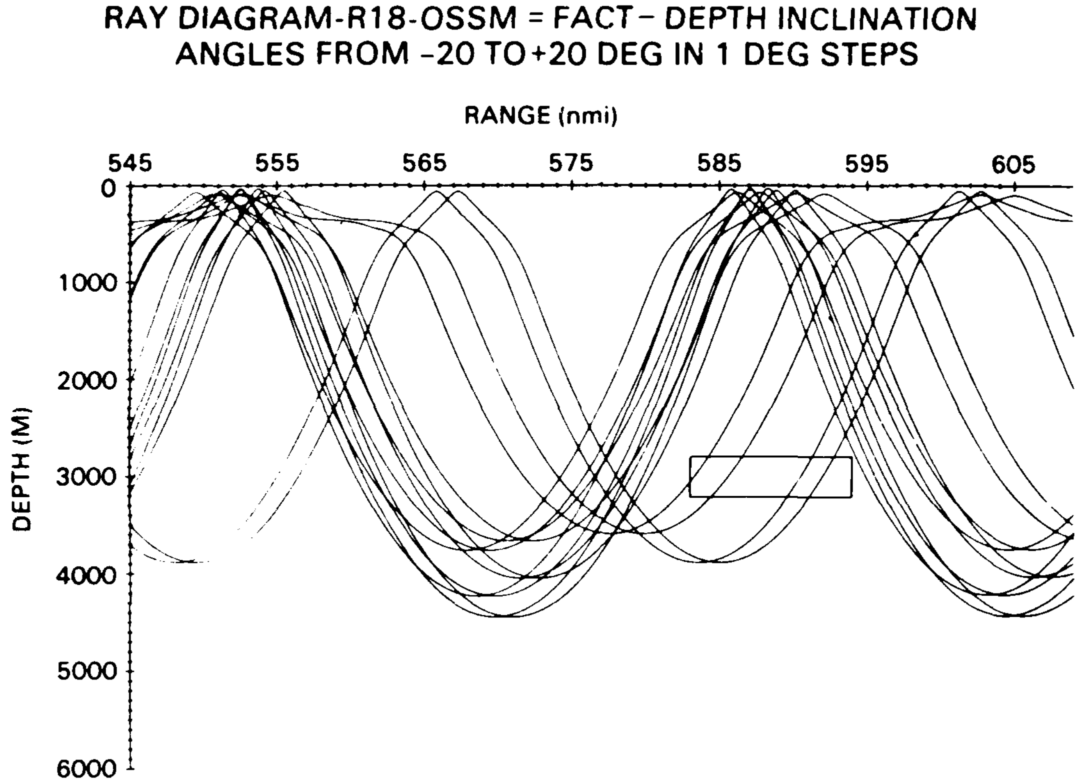
REPRESENTATIVE RECEIVED SIGNAL SPECTRUM (H1 AT TIME 27 MIN, AVG TIME 1000 SEC)



Slide 7

Although the bandwidth was relatively constant one could observe some dynamic changes in spread and wander of the signal in both space and time.

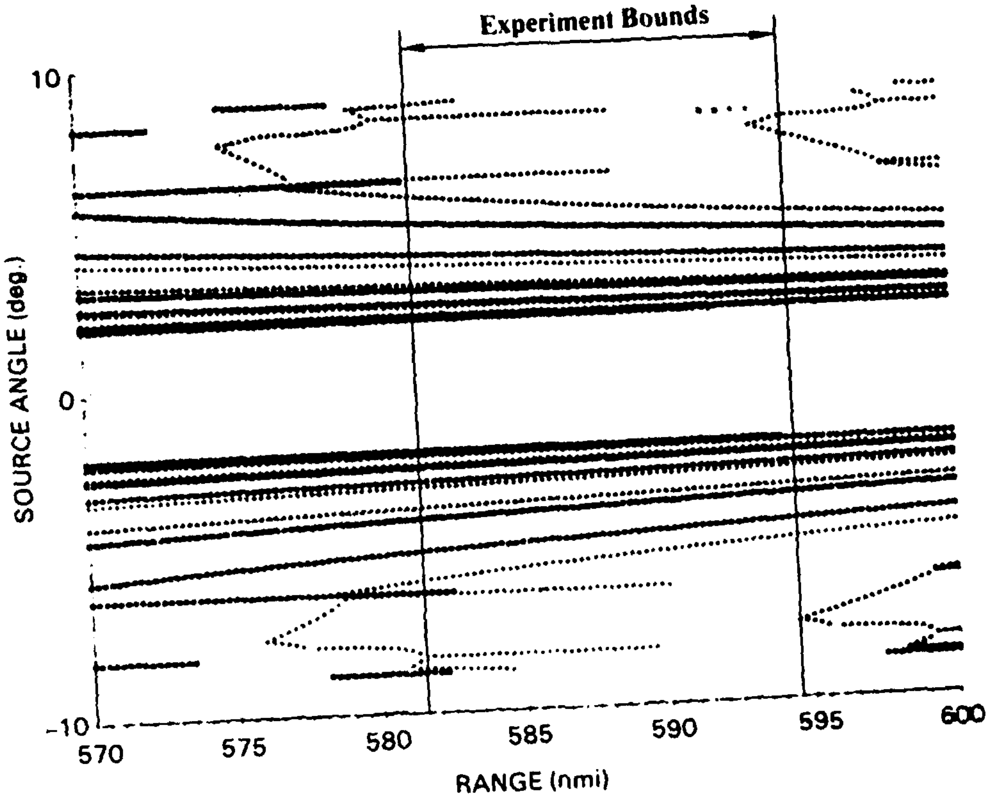
In this slide, you can see at least the hint of a second peak. This led us to pursue further studies. Could we say anything from this data about multipaths? Secondly, how much would this variability affect a standard second order least-square curve fit to the data?



Slide 8

To get an estimate of the possible multipaths that might be present, we used the predictions of the Fact option of the generic sonar model developed by Weinberg. A ray plot is shown, with the window that was covered in this experiment at the lower right. Since the source is opening range, we are sweeping our 400 meter array across the rays, traveling out to longer ranges.

— Slide 9, please. —



Slide 9

The modeling program identifies specific rays both as to source angle and propagation loss for a given depth and range. For a given receiver depth, some possible ray source angles are shown as a function of range.

From the predicted propagation loss, we found there were three dominant ray groups centered at initial angles of 11°, 10°, and 5° that could make a significant contribution.

Each would have a characteristic Doppler shift.

— Slide 10, please. —

FREQUENCY STATISTICS

$(\frac{\Delta f}{f}) \times 100$ (% DOPPLER SHIFT)

SPACE AVERAGE

TIME (min)	$\bar{S}$	σ
0	.2992	.0015
9	.2994	.0009
18	.3000	.0007
27	.3016	.0012
36	.3037	.0010
45	.3040	.0019
63	.3027	.0029
72	.3020	.0035
81	.2998	.0049
90	.3009	.0021

TIME AVERAGE

HYDRO-PHONE	$\bar{T}$	σ
H_1	.3009	.0014
H_2	.2998	.0011
H_3	.3026	.0020
H_4	.3021	.0028

Slide 10

We present our frequency statistics as percentage of Doppler shift. Again the averages and standard deviations are uniform in both space and time. These averages are approximately equal to the average shift of the 11°, 10°, and 5° rays combined. So the variability is certainly, from a frequency point of view, compatible with multipath predictions. We could not resolve individual ray packets, say the 5° group, from our averages.

— Slide 11, please. —

INTENSITY STATISTICS
(COMPARISON TO FIT)

SPACE AVERAGE

TIME(min)	$\bar{S}_{(dB)}$	$\sigma_{(dB)}$	$\bar{S}_F$	σ_F
0	9.5	2.8	9.7	2.8
9	12.4	2.9	12.2	2.8
18	13.5	2.1	13.1	2.2
27	13.4	3.1	13.0	2.8
36	14.3	3.2	14.1	2.9
45	11.4	3.5	11.2	3.2
63	10.8	3.4	10.8	3.0
72	10.4	3.3	10.5	3.2
81	7.3	3.4	7.7	2.9
90	7.2	3.1	7.6	2.7

TIME AVERAGE

HYDRO-PHONE	$\bar{T}_{(dB)}$	$\sigma_{(dB)}$	$\bar{T}_{F(dB)}$	$\sigma_{F(dB)}$
H_1	12.5	3.4	12.5	3.0
H_2	9.2	2.8	9.5	2.3
H_3	12.0	3.4	11.8	3.1
H_4	11.9	2.8	11.6	2.9

Slide 11

Finally, we present the intensity data statistics and compare them to statistics obtained from a least-squared second order curve fit to the data (shown here with the subscript F).

First of all, the comparison of the actual and fitted data is very close, within 0.5 dB. This implies that the use of this fit to estimate signal bandwidth is acceptable.

Again, for intensity the space and time averages and their standard deviations are similar. Note, however, the range of the averages: a spread of over 3 dB for the time averages and over 7 dB among the space averages.

CONCLUSIONS

1. Bandwidth: very narrow, stable for our conditions.

2. Intensity: fluctuations on the order of ± 3dB in both space and time.

3. Frequency: small variations over both space and time.

Slide 12

We can summarize our results as follows:

- The bandwidth remained very narrow at this long range. Simple scattering was not a dominent factor.

- The intensity as a function of frequency can be approximated by single peak; but fluctuation in intensity level is significant, at least ± 3 dB.

- The observed frequency variation would support multipath theory. We do not appear to have been able to resolve any dynamic events, so we cannot say anything about their affect on the data.

In conclusion, at long ranges, narrowband processes may be fluctuating significantly in level due to multipath interaction, but they will still be narrowband.

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Thank you.

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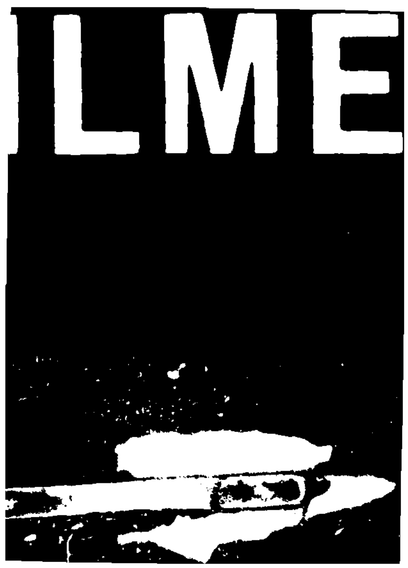
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